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U.S. and Whom? Structures and Communities of International Economic Research

Raphael H. Heiberger
University of Bremen, raphael.heiberger@uni-bremen.de

Jan R. Riebling
University of Bamberg, jan.riebling@uni-bamberg.de

Abstract

Most studies concerned with empirical social networks are conducted on the level of individuals. The interaction of scientists is an especially popular research area, with the growing importance of international collaboration as a common sense result. To analyze patterns of cooperation across nations, this paper investigates the structure and evolution of cross-country co-authorships for the field of economics from 1985 to 2011. For a long time economic research has been strongly US centered, while influencing real-world politics all over the globe. We investigate the impact of the general trend of increasing international collaboration on the hegemonic structures in the "global department of economics." A dynamic map of economic research is derived and reveals communities that are hierarchical and structured along the lines of external social forces, i.e. historical and political dimensions. Based on these findings, we discuss the influence of the core-periphery structure on the production of economic knowledge and the dissemination of new ideas.

Keywords

Scientific collaboration, economics, dynamic networks, network visualization

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Introduction

In this article, we treat countries as primary research subjects in order to investigate the increasing global connection of social life. The process of globalization has not only left its trace in altering trade patterns or extending travel destinations, also the way scientists work has changed. In the last 30 years, international collaboration has led to stronger relations between researchers in different countries and a worldwide scientific network has emerged that includes the former Eastern Bloc nations (Doré et al. 1996; Georghiou 1998; Glänzel 2001; Glänzel and Schubert 2005; Persson, Glänzel, and Danell 2004). Yet, international scientific collaboration is still dominated by a core of western countries with the US at its center (Leydesdorff and Wagner 2008; Wagner 2005). The work of Zitt and colleagues (2000) also reveals that patterns of collaboration across countries follow historical and political partnerships. We expand on these insights in two ways: First, we go beyond the dyadic perspective and take a closer look at the broader relationship structures in which the collaborations are embedded in terms of networks and communities. This allows us to specify the political influence spheres which we believe to be decisive factors. Secondly, we look at the underlying dynamics of international scientific relationships. Since the world changed drastically since the 1980s, it is reasonable to assume that the network structure would adjust.

In general, the study of scientific collaboration is facilitated by the richness of available data and provides insights about the creation of ideas and the underlying structure of scientific discoveries, which makes it an issue that grows more and more important in advanced economies (Kronegger, Ferligoj, and Doreian 2011; Light and Moody 2011). Despite the widely undoubted impact that scientific research has on modern, innovation-based societies and the availability of appropriate data, the global relationships within the discipline of economics have not yet been examined. At the latest, recent financial turmoil has strikingly shown that the paradigmatic dominance of the neoclassical approach needs to be reformed (Hodgson 2009; Keen 2011). This orthodox way of doing economics is linked to the dominant role of the US within the field. For instance, in a comprehensive (and for us, also eponymously inspiring) study Jishnu Das et al. (2009) identified a far higher likelihood of being published in the five most important journals if the paper`s topic is US-related. The same pattern of centralization exists on an institutional level. Only a handful of American universities produce the most visible publications (Coupé 2003; Kalaitzidakis, Mamuneas, and Stengos 2003; Kim, Morse, and Zingales 2006). These elite institutions are highly connected with a core network of economic journals, which is also very consistent over time (Liner 2003; Stigler, Stigler, and Friedland 1995). Hodgson and Rothman (1999) analyze the institutional background of editors and authors of those economic journals and find that around 80 percent of authors and editors alike are affiliated to US institutions. On a personal level, Goyal et al. (2006) discover a growing large component in economic research collaboration that is due to few interlinking (US based) star economists.

But is a giant monolith dominating the entire discipline or is the global situation more complex? Questions of international embeddedness and change within the economic research community seem not only important for the sociology of knowledge, but also for practitioners since economics has always played an important role in the legitimation and application of different national policies, ideologies and institutions (e.g. Fourcade-Gourinchas 2001; Hall 1989; Schumpeter 2013). For a long time, economics has been strongly intertwined with politics in many institutions (e.g. IMF, World Bank, Central Banks, stock regulations like the SEC), and ideas developed in economics often influence national and international economic structures and laws. Or as John Maynard Keynes (1973:383) noted: “The ideas of economists and political philosophers, both when they are right and when they are wrong, are more powerful than is commonly understood.”

Methodologically, the paper applies techniques of the social network analysis approach. With the global network of collaborating economists we concentrate on the relationships between countries, which offer an alternative of the investigation of national shares of publication or citations (Leydesdorff et al. 2013). These collaboration networks between scientists can be seen as a “new

invisible college" (Crane 1972; Wagner 2008), spanning the globe and connecting researchers from different countries. To identify alterations in the composition of this "global department of economics," we first look at the expansion of the field in general and investigate individual positions of countries therein. Subsequently, we integrate these singular developments in the evolution of the whole network, revealing a core-periphery structure and communities with particularly dense relationships that run along historical and political boundaries.

Data and Methodology

We collected a data set that represents virtually the entire economic field.[1] The general selection based on the 100 most important economic journals identified by Das et al. (2009), from which 87 were available in Thomson Reuters Web of Science, with missing values biased in regard to B- and C-journals. The raw sample contains about 150,000 articles, spanning from 1985 to 2011. Circa 45,000 (~30%) of these have more than one author. Our focus in this paper, however, lies on the level of international collaboration, hence, only publications with two or more authors from different countries are considered. The country affiliation depends on the institutions of the authors. In the case that two or more institutions are provided per author, only the first ("home") institution is taken. Thus, around 5,500 (~3.7%) from the initial documents were *internationally coauthored* and remained in the final data set.

Each country pair was used as an edge in a multigraph, that is, a graph with parallel lines between nodes, where each line represents one instance of cross-country collaboration. For example, economists in the US and Canada have cooperated 1376 times in the observed period, corresponding to the same number of edges between both nodes. This raw number of co-authorships between two nations is normalized as an indicator of international collaboration strength (Boyack, Klavans, and Börner 2005; Glänzel 2001):

$$w_{ij} = \frac{\sum p_{ij}}{\sqrt{\sum d_i \sum d_j}} \quad (1).$$

The weight w_{ij} between country i and j consists of the sum of joint publications (p_{ij}), divided by the geometric mean of total publications of each country (degrees d_i and d_j, respectively). The normalization is necessary in order to reveal latent structures that could otherwise be overlooked due to stars in the network (e.g. the US) and their mere size of research output (Leydesdorff 2007a, 2007b; Leydesdorff and Wagner 2008).

In general, the science system is based on networks of scientists who write paper together and know one another (Newman 2001). It has been suggested that out of such interactions of single actors arises a complex system with specific topological and dynamical principles (Barabási et al. 2002). Under these assumptions, we would expect the network to exhibit a high tendency towards homophilic relations in regard to the prestige of scientists and their "attractiveness" to work with colleagues from different countries. A deviation from this pattern on the other hand would point to the influence of external constraints, most likely in the form of political, linguistic and historical boundaries between nation states. If our assumptions are correct and political and cultural influence spheres are central to the formation of scientific collaboration on a global level, we would expect to see a network marked by *heterophilic* relationships and following a shifting political landscape.

In order to investigate this system more closely, we apply several network analytical tools, roughly divided into positional measures and community detection algorithms. To structure the positional metrics, we distinguish between medial and radial measures according to Borgatti and Everett (2006).

[1] Our data does only contain journal publications, but no other media, especially no books. Yet, the bias should be sufficiently low since economics is a discipline in which articles are the major form of communication (Whitley 2000).

Medial measures are used to determine the intermediate position of nodes with regard to other nodes. We employ betweenness centrality (Brandes 2001; Freeman 1979) as a measure for the mediator quality of an actor, i.e. the number of shortest paths g_{ikj} from node i to node j through the intermediary k, divided by g_{ij}, what denotes the number of geodesic (i,j)-paths. Thus, the betweenness centrality is defined as:

$$B_k = \sum_{i,j} \frac{g_{ikj}}{g_{ij}} \quad (2).$$

It indicates the control that a node exerts over the communication of others, and can be interpreted as a measure for the most influential nodes in a network, who control the flow of information as gatekeepers. More specifically, it gives the probability that a country k is involved into any communication between i and j, serving as a bridge between both.

The main aim of radial measures is to specify a node´s position in terms of how many connections are emanating from it. This is equivalent to degree of node i (d_i) in (1). To control for the size of the network this number is normalized by the maximum number of connections possible (*N-1*). Thus, Freeman´s (1979) degree centrality gives us the fraction of realized connections for a certain node.

Complementary to individual centrality scores, we investigate the structure of the whole network in terms of hierarchy. One of the most common techniques to do this is to calculate the centralization of connections (Freeman 1979). In our case, the degree centralization measures the concentration of collaboration, i.e. the strength of deviation between high and low degree values, with d^* as the highest degree of any node in the network. Formally, this can be written as:

$$C_D = \frac{\sum_{i=1}^{N}[d^* - d_i]}{(N-1)(N-2)} \quad (3).$$

To measure not only the hierarchy of countries but to learn more about which country is connected to what others, we calculate the assortativity of nodes to describe the degree of similarity of coauthors in terms of their own connections. Technically, this is the Pearson-correlation between the edges (Newman 2003). For instance, social networks are known to be often assortative by race, gender or language. In our case, a high score of assortative mixing by degree means that countries with many collaborations would be linked to other well connected nations, or, the other way round, economists from peripheral countries write paper rather with their like. Accordingly, a low assortativity coefficient indicates a disassortative network, i.e. countries prefer connections with others that are unlike them in terms of relationships.

In addition to hierarchical properties, our paper tries to detect communities within the network. Those groups consists of countries in which connections are unusually dense and have only loose connections to other subgroups (Girvan and Newman 2002). To detect them, we applied the modularity approach of Clauset et al. (2004) by using the algorithm of Blondel et al. (2008). This method is not only computationally efficient but also provides valid modularity maxima (Lancichinetti and Fortunato 2009). Complementary to the partition, the modularity score serves as an indicator for the compartmentalization (modularization) of a network (Newman 2004, 2006). For weighted networks it is defined as:

$$Q = \frac{1}{2m}\sum_{i,j}\left[w_{ij} - \frac{d_i d_j}{2m}\right] f(c_i, c_j), \ (4).$$

where $m = \frac{1}{2}\sum_{ij} w_{ij}$, and c_i is the community of node i and j, respectively. The function is 1 if $c_i = c_j$ and 0 otherwise. It calculates the difference between realized and expected connections between two nodes. The modularity score Q rises as more possible connections are realized within a given

community in relation to connections to nodes in other communities. Thus, Q measures the division of a network in modules and the identifiability of these groups in relation to each other.

The calculation of the centrality scores and other network measures was done using the "NetworkX" module for Python 2.7 (Hagberg, Schult and Swart 2008). For the community detection via the "Louvain method" described above, we used the "community"-package created by Thomas Aynaud.[2] The figures were also created in Python, using the excellent "plotly" module for interactive graphics.

Growth and Hierarchy

As in other scientific fields, the frequency of all coauthored publications is strongly rising in economics during the last 25 years, indicating a more differentiated division of labor for more specialized tasks. The dynamic of international collaborations does not match this exponential growth (upper and middle box in Figure 1). Also, the number of international coauthored documents is quite small compared to science in general (around 20% reported by Leydesdorff and Wagner 2008). However, the share of economists that work together across national borders increased considerably. In 1985, only 1 out of 100 papers was produced by economists in different countries, in the most recent years it was nearly every tenth paper. Especially in the last few years this development picked up some steam.

The different patterns of growth reinforce the idea that there are mechanisms at work which influence and hinder scientific collaboration across countries. This can partly be attributed to language barriers (Hoekman et al. 2013; Marshakova-Shaikevich 2006). Yet with the increasing dominance of the English language as *lingua franca* of science this explanation seems not sufficient. Instead we argue that while language may play a role in the facilitation of cross-country collaboration, geo-political influence spheres are a more important factor. If we look at the number of countries involved in cross-country collaboration (lower box in Figure 1), we see that a first wave of "new" countries came into play after the fall of the Iron Curtain. A geopolitical process started at this point in time, which led to the accelerating trend of rising international exchange of persons, goods and cultural artifacts and is commonly referred to as globalization. This development is closely matched by all three growth patterns of scientific collaborations in Figure 1. After a rather stabile time around the millennium, the number grew significantly in the most recent years and indicates a strong, ongoing trend.

Figure 1: Growth of International Economic Research Collaboration

Despite the increased cross-border collaboration around the world, the paramount actor on the international level was, and still is, the USA. The degree centrality in the late 1980s and 1990s was especially high, with values above 0.8 (Figure 2). Although it is slightly declining since then, the USA is still the most central player in economic collaboration. Beyond the rather consistent role of the US, some changes exist in the structure of economic collaboration. The big European countries expanded their international collaboration efforts during the 1990s, particularly England and Germany. As a consequence, the relative distance between the US and those countries decreases drastically in the years after 2000. Hence, even though there is no change at the top, all major Western countries increased their efforts to collaborate with colleagues from other nations, which make the centrality of the US less "star network like."

[2] perso.crans.org/aynaud/communities

One further issue of global scientific debate is the role of China in the last decade or so. Some prominent observers see Chinese researchers as number one challenger of the US hegemon (Mirowski 2010). Other than in economic or political affairs, China has not yet achieved a dominant role in economic research. It is only marginally improving in terms of collaboration, indicating—at least for economics—that the "overtaking of Chinese scientists" (e.g. Shukman 2011), copiously discussed in popular media, is not yet conceivable.

Figure 2: Degree Centrality for Selected Countries

Additionally, the betweenness centralities in Figure 3 indicate that the ability of Chinese economists to mediate between scientists of different countries hardly exists. In contrast, US economists still play the most important part in connecting researchers worldwide, with the major European countries increasing their mediator positions only slightly, if at all. However, there is one exception—England. Together with the clearly decreasing ability of the US to mediate between researchers of different countries in the new millennium, it seems that the dominance is crumbling, as least relatively. In combination with the overall growth of the field, this implies that fewer of the "new" participants in economic research are connected via US economists. Thus, this development indicates that nowadays exist "supplementary options" to connect economists in peripheral countries to the core, a process that will also be clearly visible in Figure 5 and the movie. However, no other "beacon" of similar propensity has, as of yet, emerged that would mediate between peripheral countries and the core, making US economists still the most important actors in respect of mediator qualities as well as overall collaborations. Therefore, the hierarchical structure in economic collaboration seems rather untouched, even in the years after 1990, with the Iron Curtain falling and former communist states being integrated in the global science community.

Figure 3: Betweenness Centrality for Selected Countries

Structure and Communities

The notion of relative stability in terms of the individual positions of countries in the global economists´ collaboration network is underlined in Figure 4. All three structural measures are rather steady over time. Again, the heavily discussed expansion of the scientific community has only limited effects on the overall structure of the field. The modularity of economic collaboration is rather low, compared to other social networks (Newman 2006). One possible reason is the generally unified core of economic research that lies within the neoclassical approach (Reay 2012). The *homo oeconomicus* and the nearly exclusive use of quantitative methods are widely accepted theoretical and methodological foundations of the discipline, making it rather easy to collaborate globally. We suggest this would be different in a theoretical and methodological diverse discipline, e.g. in sociology (Abbott 2000; Moody 2004).

Figure 4: Modularity, Degree Centralization and Assortivity

Thus, the entire structure shows a relative stability over the last three decades and the, by far, most important collaboration partner is the US. However, the permanently negative assortativity in Figure 4 represents a heterophile degree distribution. This tendency is very uncommon for social networks (Newman 2003). As in most social networks, we would expect a network generated solely by the preferences of scientists to be assortative. Instead, there is a permanent negative assortativity. We consider this as further evidence for the influence of external factors (i.e. political and cultural influence spheres) driving the development of cross-country collaboration.

Moreover, the development of the correlation by degree shows a slump during the integration of the former Eastern bloc countries, and rises slowly since then. The relatively abrupt global opening seemed to cause even more disassortative countries to work together. After this phase of integration the negative mixing is gradually decreasing, but still, mostly unequal partners collaborate together.

As we will see, most communities have some sort of "beacon" or broker that is distinguished by the amount of degrees from the other community members.

To examine the evolution of the economic field in terms of international collaborations in greater detail, we created a short movie in Gephi (gephi.github.io). Therein, the displayed communities are based on all international collaborations between 1985 and 2011. This step is necessary since community detection is still a rather sensible issue in social network analysis (Fortunato 2010). We experienced such problems using Gephi's modularity algorithm, where the number of communities changed—under the same settings—with every running. Therefore we used the Python-algorithm by Thomas Aynaud mentioned above, which provides steady results for both numbers and members of communities. For a better overview, the whole network with its subsequent partitions is shown in Figure 5.

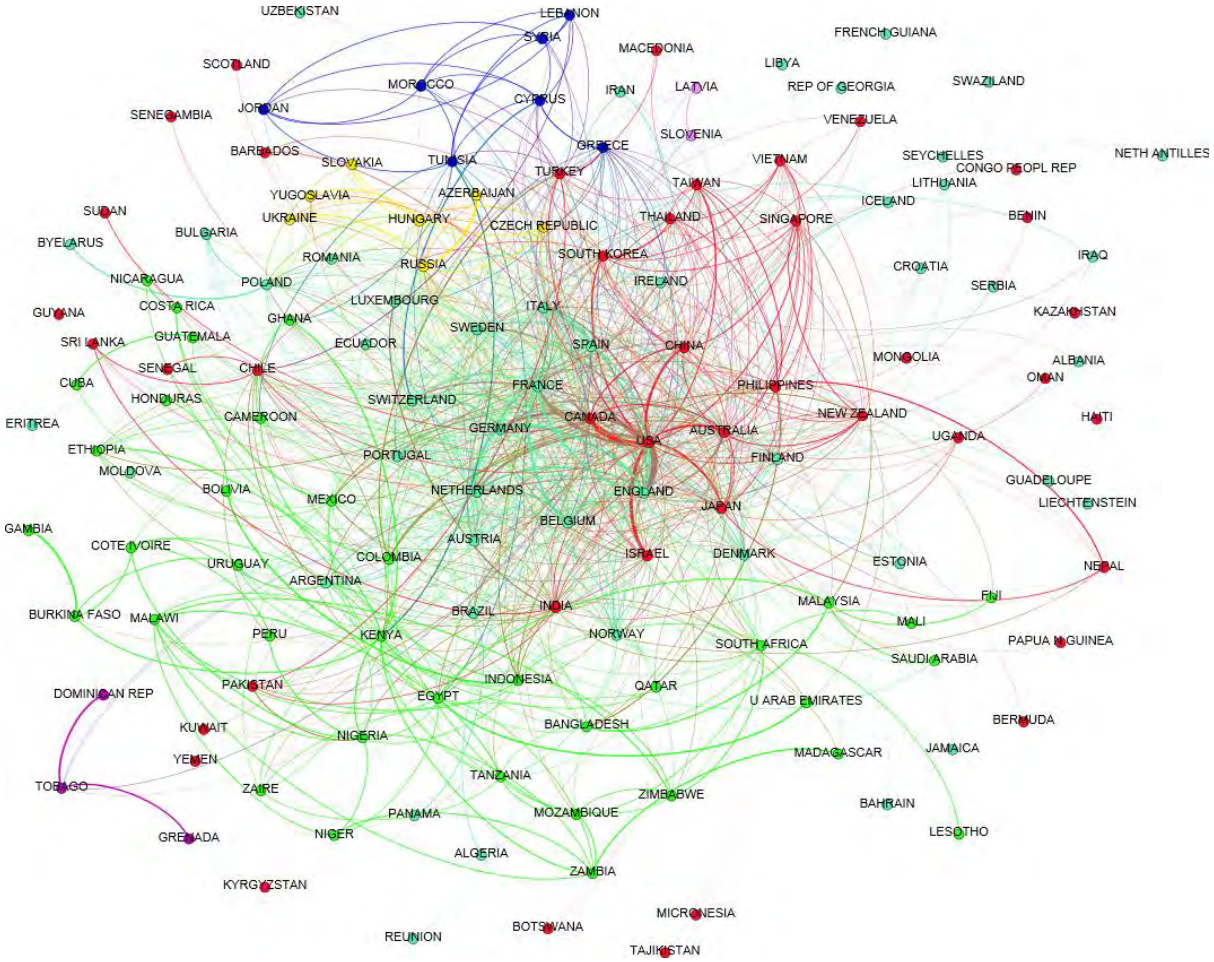

Figure 5: Map of Economic Research Collaboration between 1985 and 2011

The nodes of the communities are turquoise ("Europe" 32.4% of all edges), red ("Pacific," 28.9%), green ("Emerging," 25.5), blue ("East Mediterranean," 4.8%), yellow ("Post-Communist," 4.8%), purple ("Caribbean," 2.1%) and pale purple ("Baltic," 1.4%). The edges inside a community are drawn in the same color as the community and the positions are defined by the Fruchterman-Reingold algorithm.

The community detection reveals two major groups dividing the center, another large and two smaller cliques sharing the periphery and two very small communities. The largest group in terms of relations is the European cluster, with the key members Germany, Netherlands and, somewhat surprisingly, England. It seems that the scientific connection to the continent is in sum more important for English economists than for their US colleagues. However, with Argentina and Brazil some former European

colonies in Latin America are also part of the community. The countries arranged around the US spread mostly along the Pacific, from Canada through Chile and Australia to China and Japan. It forms a similar large group (due to the US) and includes mostly developed nations outside Europe like Australia or Japan. Especially the tight center of the network is divided by these two clusters. In contrast, the periphery is mostly defined by developing countries spreading around the center. As in real-world economic deprivation, these countries are located in the Southern hemisphere, in Africa, Middle and South America. Mexico is the "beacon" of this community and their most influential member. Interestingly, Brazil and Argentina hold stronger relations to Europe, while Chile is more oriented towards the US centered community than to their Latin American neighbors. Only relatively deprived countries like Bolivia, Uruguay or Peru belong to the "Emerging" community. Also in the periphery we find the "Post-Communist" community, consisting of former members of the USSR (e.g. Russia or the Ukraine) and a cluster of mostly Mediterranean countries. Finally, there are two very small clusters of countries in the Caribbean and the Baltic.

Corresponding with the modest modularity scores over time, the network is only slightly compartmentalized, with the great majority of collaboration going on within and between the US and European based communities. Inside each group relatively diverse countries assemble in regard to their output in economics. The USA in the Pacific community, Mexico as leading Emerging nation or England and Germany in the European community. As the assortativity scores over time suggested, node relations correlate negatively with each other and countries mix mostly with others *unlike* them.

In addition, the communities reflect roughly the topology of international politics and economic differences. Relatively rich and developed countries gather in the Pacific and European communities. The global south with mostly poor countries, is also relatively peripheral in economic research and is only rudimentary linked to the other communities. Thus, besides distinct traditions of economics that shape the collaboration structure across countries, the world map reveals clustering tendencies between scientifically diverse countries, that are, however, historically, politically and/or economically related.

Utilizing the movie to investigate the network evolution, we can observe how the participation within the described communities changes over time. In the beginning there are only few, mostly Western countries. The first wave of expansion happens after the fall of the Berlin Wall, as is also shown quantitatively in Figure 1. In the aftermath of the crush of the USSR, the first Eastern European countries appear in the network. During the 1990s this group gets bigger (~ 0:08s), as does the whole periphery. Most of the new participants stem from the global South. Some of them are mostly connected to other peripheral countries ("green"), some to the US centered Pacific cluster. But only very few—actually only Argentina and Brazil (ignoring very small countries that just pop up briefly)—develop a strong relationship to the European field of economics. The US centered cluster, in contrast, becomes much more diversified during the same period. In the new millennium the expansion visibly slows down (around 0:17s), with the world´s larger countries already taking part in global economic research. Only for the last few years (and seconds) we see a further growth in the periphery.

This dynamic emphasizes the hierarchical properties of the network. Furthermore, the network evolution makes the changes in the political landscape and their influence on scientific collaboration patterns even more visible. The network starts out as dominated by a strong center which is formed mostly by the US and large European countries. Until the 1990s this structure grows mostly by reinforcing the center, or in other words, the central members are intensifying their relations. The drastic political changes following the fall of the Iron Curtain are reflected in the network by the connection of former USSR member states in the periphery and the first wave of global expansion. At the end of the 1990s the European and Pacific clusters become more independent of each other and include different members in their respective community (i.e. the core). This process is mainly responsible for the "bifurcation" of the center. It is important to note that the network still retains its strong hierarchy and grows by adding "levels" in terms of peripheral nodes to the existing topology.

The “new” arrivals seem thereby oriented along sociocultural ties, for example, in terms of Metropole powers and their colonies (European community) or shared historical experiences (Post-Communist countries). Thus, countries who join the network are not just integrated within the main core but are rather located as another layer around the (bifurcated) center.

Conclusion

If one considers each scientific publication as an idea and the authors as their conveyors, then the global exchange of ideas has drastically increased in the last 25 years. In our paper we have studied the international collaboration network of economists, to learn more about the way researchers interact across borders and the distribution of the “global department of economics.” Especially in times of real-world economic slumps it seems important to take a closer look at the structures and mechanisms behind the production of knowledge in economics.

The international network of economists follows a clear core-periphery organization, with the US at its center. Like in other disciplines, collaboration in economics expanded heavily after the fall of the Iron Curtain. During this process, Europe intensified the relations with “new arrivals,” i.e. countries of the periphery accessed the field with co-authorships following established historical and political borders. Due to a history of exploration and colonization, it seems that traditional connections helped European countries to rather join “their” cluster than the US dominated group. Thus, economists are more likely to work together across countries which are longstanding allies. Community detection revealed mainly clusters between culturally and historically connected nations, e.g. between Post-Communist countries in Eastern Europe. Also, the US has especially intense relations with their political allies from India, Chile and Turkey, but only very few collaborations exist with the rest of (rather US skeptical) Latin America. However, although the network expanded heavily in the last three decades and economic publications are more globalized, the large majority of international collaborations still take place between the “usual suspects,” i.e. industrialized western countries.

The existence of a stable core-periphery structure in the global network has two, rather different, implications for the future: Optimistically, economists from peripheral countries can collaborate more often with members of the core groups. By doing so, their—supposedly less paradigmatic—ideas could be distributed relatively easy to other central actors (and therefore to important institutions and journals). As a consequence, a larger variety of economic knowledge would be possible, e.g. about the modes of production in developing countries, different ways of consumption or ecological problems of the global South. Secondly, and more pessimistic, the cohesive and persistent core could also monopolize knowledge and collaboration resources. The great resilience of the hierarchy and community structure points to processes which reproduce the established structure. In this case, the opportunities for developing countries to join the “new invisible college” proposed by Wagner (2008) seem to be a long way off. This could very well be a future obstacle to the free exchange of ideas in economics, which is science greatest resource and a fundamental driver of innovations.

As has been shown for the (rather homogeneous) countries of the EU (Hoekman et al. 2013), political incentives can help to establish relations between dissimilar countries. In order to facilitate and enhance the inclusion of peripheral countries in economic research, hence, worldwide incentives for joint research efforts could be a useful approach (e.g. provided by financial institutions like the World Bank or IMF). From a network perspective, this should lead to an increasing flow of ideas around the globe. For this purpose, the results of our paper would provide rich material about the dynamics and structural properties of the global community of economists.

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